MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2016/2017

EEE 3076 – POWER ELECTRONICS

(LE, EE, CE, NE)

12 OCTOBER 2016
2.30 P.M. to 4.30 P.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages including cover page with 4 Questions only.
2. Answer ALL questions. All questions carry equal marks and the distributions of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

An IGBT is used as a switch for a converter driving an R-L load. The input voltage is 400 V and estimated maximum output current is 30 A. The switch is operated at 25 kHz with 50% duty cycle.

IGBT Specifications @ $T_j = 25$ °C

	Parameter	Typ. Value	Units
V_{CES}	Collector to Emitter Voltage	600	V
$I_{NOMINAL}$	Continuous Collector Current	35	A
$V_{(BR)CES}$	Collector to Emitter Breakdown Voltage	600	V
$V_{CE(ON)}$	Collector to Emitter saturation voltage	1.6	V
I_{CES}	Collector to Emitter leakage current	1.0	μA
$t_{d(on)}$	Turn On delay time	46	ns
t_r	Rise time	33	ns
$t_{d(off)}$	Turn Off delay time	105	ns
t_f	Fall Time	44	Ns
R_{ON}	ON Resistance between Collector and Emitter	70	mΩ

a) Sketch the waveform for I_C and V_{CE} for one complete switching cycle. [4 marks]

b) Compute the static loss [7 marks]

c) Compute the dynamic loss [11 marks]

d) Compute the total loss [3 marks]

Continued...

Question 2

a) Design a full wave rectifier to supply an average DC voltage of 180 V to a Resistive-Inductive load. The maximum average power required by the load is 5 kW. Input AC voltage is 230 V, 50Hz.

i) Sketch the circuit diagram.

[4 marks]

ii) Compute the maximum average load current.

[5 marks]

iii) What should be the minimum current and breakdown voltage for the switch used in the rectifier?

[4 marks]

iv) Assuming the load inductance is large, sketch the input AC current waveform relative to input AC voltage waveform.

[5 marks]

b) A three-phase half-wave uncontrolled rectifier is used to supply DC voltage to a heater. Sketch the load voltage, diode current, and diode voltage waveforms. [Sketch the waveforms in the graph given in the Appendix]

[7 marks]

Continued...

Question 3

(a) Design a buck converter to power a load that consumes 32 W. The load requires a voltage with ripple not more than 1%. The input voltage V_{in} = 60 V and duty cycle D = 0.4. The switching frequency used to operate the converter is 25 kHz. Examine the converter to make sure it operates in the continuous current mode. Assume all the converter components are ideal. Choose suitable inductor and capacitor rating based on tables 3a and 3b.

Table 3a : Inductor Ratings

L (μH)	50	100	150	250

Table 3b : Capacitor Ratings

C (μF)	100	500	1000	2000

[13 marks]

(b) A buck-boost converter supplies 70 W to a load at a current of 5 A from a 40 V dc source. The switching period is 130 μs and the value of the inductor is 250 μH. Determine the following:

i) The duty cycle D. [4 marks]

ii) The minimum and maximum inductor current (I_{Lmin} , I_{Lmax}). [4 marks]

iii) The average input current. [2 marks]

iv) The average diode current. [2 marks]

Continued...

Question 4

a) A pulse width modulated full bridge inverter has a dc input voltage of 120 V, and a resistive load of 8 Ω. The inverter is operating at a duty cycle of 67 % with a frequency of 60 Hz. Determine :

i) The r. m. s. value of output load current (i_o) and output load voltage (v_o) for the first, third, and fifth harmonics.

[8 marks]

ii) The total power delivered to load for each of the above harmonics.

[6 marks]

iii) The total harmonic distortion of the output current.

[2 marks]

b) A series resonant inverter shown in Figure Q4 is used in an induction heater. Given the following circuit parameters:

R = 3 Ω, L = 80μH, C =10μF, Output frequency = 3 kHz,

i) Determine the operation mode (overlapping or non-overlapping) of the inverter.

[6 marks]

ii) Calculate the maximum permissible output frequency if IGBT off time is 100 ns.

[3 marks]

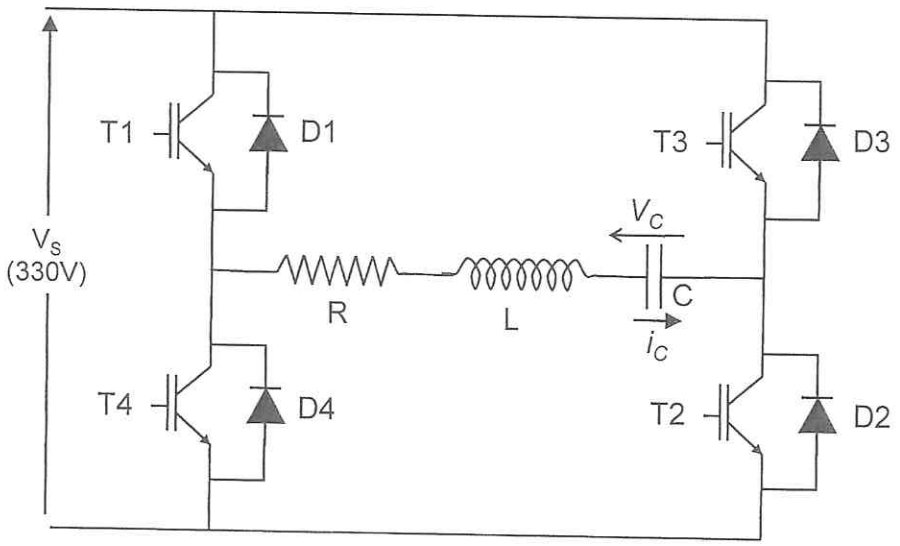

Figure Q4

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Examination Formula Sheet (Rev 3.0)

AC-DC Converters

Single Phase Uncontrolled Rectifiers (Half wave) , R load	Single Phase Uncontrolled Rectifiers (Half wave), RL Load
$V_{o,avg} = \frac{\sqrt{2}V_{S,rms}}{\pi}$, $V_{o,rms} == \frac{V_{S,rms}}{\sqrt{2}}$	$V_{o,avg} = \frac{\sqrt{2}V_{s,rms}}{2\pi}[1-\cos(\beta)]$ $V_{o,rms} = \frac{V_{s,rms}}{\sqrt{2\pi}}\sqrt{\beta - \frac{\sin 2\beta}{2}}$ $\beta \approx \pi + \theta$, $\theta = \tan^{-1}\left(\frac{\omega L}{R}\right)$
Single Phase Uncontrolled Rectifiers (Bridge Full wave)	Three Phase Uncontrolled Rectifiers (Half wave)
$V_{o,avg} = \frac{2\sqrt{2}V_{s,rms}}{\pi}$, $V_{o,rms} = V_{s,rms}$	$V_{o_avg} = \frac{3\sqrt{3}V_{l-n}}{\sqrt{2}\pi}$, $V_{0_rms} = 1.19V_{l-n}$
Three Phase Uncontrolled Rectifiers (Full wave)	Single Phase controlled Rectifiers (Half wave)
$V_{0_avg} = \frac{3\sqrt{2}V_{l-l}}{\pi}$, $V_{0_rms} = 0.963\ V_{l-l}$	$V_{0_avg} = \frac{V_{S,rms}}{\sqrt{2}\pi}(1+\cos\alpha)$ R Load $V_{0_avg} = \frac{V_{S,rms}}{\sqrt{2}\pi}(\cos\alpha + \cos\beta)$ RL Load
Single Phase controlled Rectifiers (Bridge Full wave)	Three Phase controlled Rectifiers (Half wave)
$V_{0_avg} = \frac{\sqrt{2}V_{S,rms}}{\pi}(1+\cos\alpha)$ R Load $V_{0_avg} = \frac{2\sqrt{2}V}{\pi}\cos\alpha$ RL Load	$V_{0_avg} = \frac{3\sqrt{2}}{2\pi}V_{AN}\left(1+\cos\left(\pi/6+\alpha\right)\right)$
Three Phase controlled Rectifiers (Full wave)	
$V_{0_avg} = \frac{3\sqrt{6}}{\pi}V_{AN}\left(\sin\left(\pi/6+\alpha\right)\right)$	

DC-DC Converters

Buck Converter (CCM)	Buck Converter (DCM)
$V_o = DV_d$ $I_{L\max} = V_o\left[\frac{1}{R} + \frac{(1-D)}{2Lf_s}\right]$ $I_{L\min} = V_o\left[\frac{1}{R} - \frac{(1-D)}{2Lf_s}\right]$	$\frac{V_o}{V_d} = \frac{D}{D+\Delta_1}$ $I_o = \frac{V_d T_s}{2L}D\Delta_1$

Continued...

DC-DC Converters (cont.)

Boost Converter (CCM)	Boost Converter (DCM)
$V_o = \frac{V_d}{1-D}$ $I_{L\max} = \frac{V_d}{(1-D)^2 R} + \frac{V_d D T_s}{2L}$ $I_{L\min} = \frac{V_d}{(1-D)^2 R} - \frac{V_d D T_s}{2L}$	$\frac{V_o}{V_d} = \frac{\Delta_1 + D}{\Delta_1}$ $I_o = \frac{V_d T_s}{2L} D\Delta_1$
Buck-Boost Converter (CCM)	**Buck-Boost Converter (DCM)**
$V_o = \frac{V_d D}{1-D}$ $I_{L\max} = \frac{V_d D}{R(1-D)^2} + \frac{V_d D T_s}{2L}$ $I_{L\min} = \frac{V_d D}{R(1-D)^2} - \frac{V_d D T_s}{2L}$	$\frac{V_o}{V_d} = \frac{D}{\Delta_1}$ $I_o = \frac{V_d D}{2 f_s L}(D + \Delta_1) - \frac{D I_o}{\Delta_1}$
Flyback Converter (CCM)	**Flyback Converter (DCM)**
$\frac{V_o}{V_d} = \frac{N_2}{N_1}\frac{D}{1-D}$ $I_{L\max} = \frac{V_d D}{R(1-D)^2}\left[\frac{N_2}{N_1}\right]^2 + \frac{V_d D T_s}{2L_m}$ $I_{L\min} = \frac{V_d D}{R(1-D)^2}\left[\frac{N_2}{N_1}\right]^2 - \frac{V_d D T_s}{2L_m}$	$\frac{V_o}{V_d} = D\sqrt{\frac{R}{2 f_s L_m}}$ $I_o = \frac{V_o}{R}$

DC- AC Converters

Single-Phase Half-bridge Inverter with RL load	Resonant Converters
$v_o(\omega t) = \sum_{n=1,3,5,\ldots}^{\infty} \frac{2V_s}{n\pi}\sin(n\omega t)$ Single-phase full-bridge PWM inverter (Square Wave) $v_o(\omega t) = \sum_{n=1,3,5,\ldots}^{\infty} \frac{4V_s}{n\pi}\sin(n\omega t)$ Single-phase full-bridge PWM inverter (Quasi Square Wave) $v(\omega t) = \sum_{n=1,3,5\ldots}^{\infty} \frac{4V_s}{n\pi}\sin\frac{nD\pi}{2}\cos n(\omega t - \frac{D\pi}{2})$	$\omega_r = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$ $i(t) = \frac{V_s + V_c}{\omega_r L} e^{-\alpha t}\sin\omega_r t \quad , \alpha = \frac{R}{2L}$ $V_c = V_s\left(\frac{e^{2z}-1}{e^{2z}+1}\right), z = \frac{\alpha\pi}{\omega_r}$ $V_{cp} = V_s\left(1 + \frac{2e^{2z}}{e^{2z}+1}\right)$

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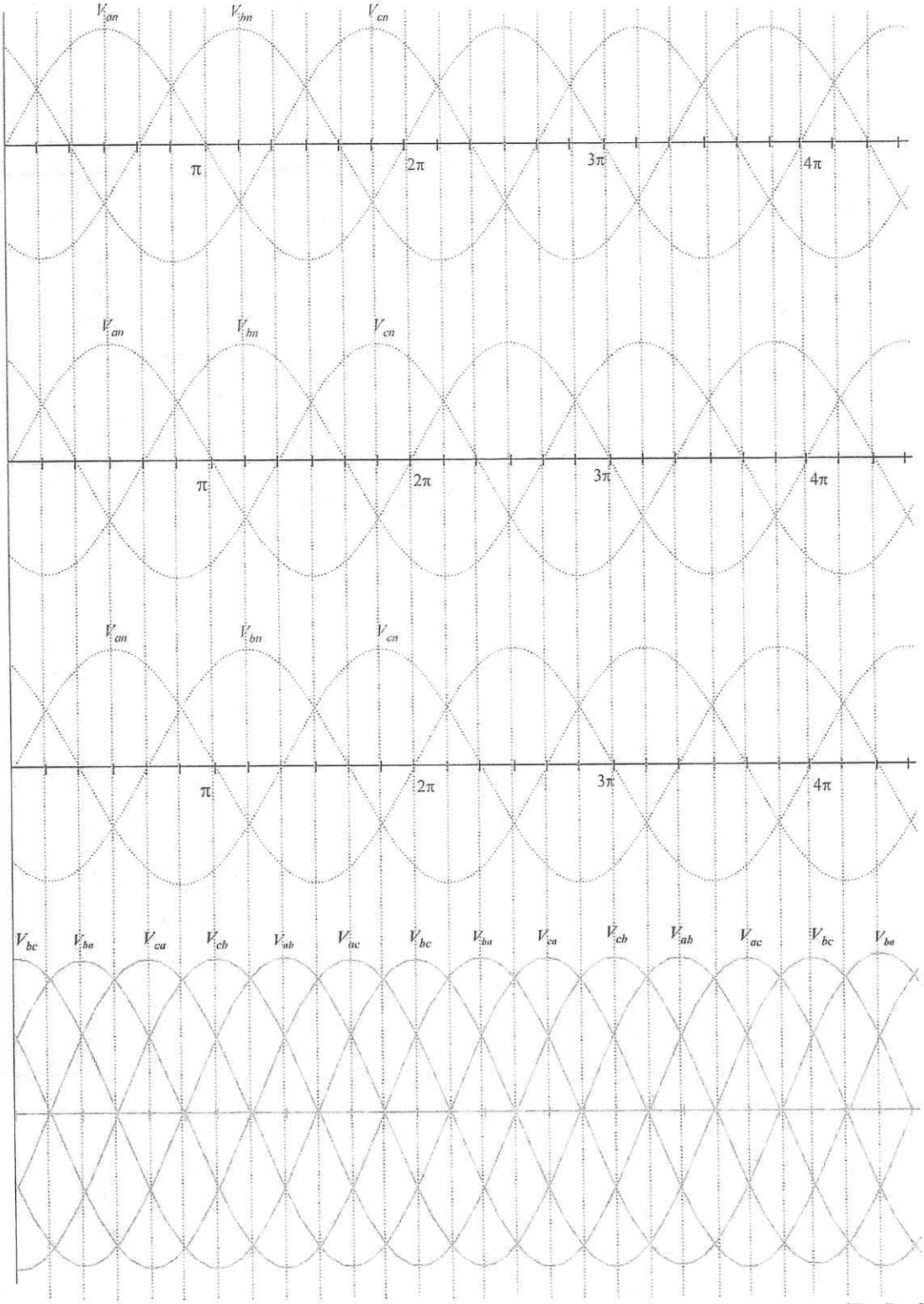
Appendix (For Question 2(b))- Please attach to the answer booklet

Student ID : ..... Table No.:.....



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